Unit 02

KINEMATICS

Introduction:

In this unit, we will study the types of motion, scalar and vector quantities, the relation between displacement, speed, velocity and acceleration, linear motion and equations of motion.

The first thing concerning the motion of an object is its kinematics. **"Kinematics means the study of motion of an object without describing the cause of motion".**

Q.1 Differentiate between rest and motion.

Ans. Rest: "A body is said to be at rest, if it does not change its position with respect to its surroundings."

Motion: "A body is said to be in motion, if it changes its position with respect to its surroundings."

Q.2 Explain with example that motion and rest are relative to each other.

Ans. The state of rest and motion of a body are relative to each other. **For example**, a passenger sitting in a moving bus is at rest because he is not changing his position with respect to other passengers in the bus. But due to observer outside the bus, the passengers inside the bus are in motion. which shows that motion and rest are relative to each other.

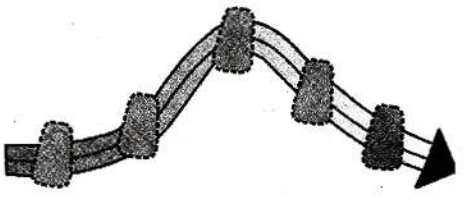
So we can say that "Rest & motion are relative states."

Q.3 Explain translatory motion and give examples of various types of translatory motion.

Ans. There are three types of motion.

(i) Translatory motion
(ii) Rotatory motion
(iii) Vibratory motion

1. Translatory Motion:- In translational motion, a body moves along a line without any rotation. The line may be straight or curved.



Translatory motion of an object along a curved path.

For example

(1) A car is moving along a straight line has translational motion and an aeroplane moving in straight line is in translational motion.

(2) A car moves along a curved path without rotation. This is the translational motion of the object. Riders moving in a Ferris wheel are also in translational motion. Their motion is in a circle without rotation.

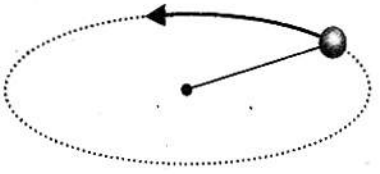
Translatory motion of riders in Ferris wheel

(a) Linear Motion :- "If a body moves along Straight line then the motion of a body is known as its linear motion".

Example: i) aeroplanes flying straight in air.

ii) objects falling vertically down are also the examples of linear motion.

(b) Circular Motion:- "The motion of an object in a circular path is known as circular motion".



For example:-

(1) Motion of earth around the sun.

(2) Motion of stone tied to string is a circular motion.

(3) A bicycle or a car moving along a circular track possesses circular motion.

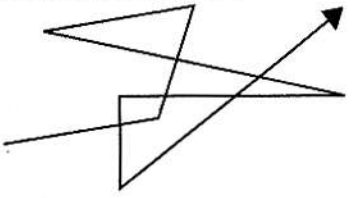
(c) Random Motion:-"The irregular motion of an object is called random motion".

Examples

(1) Motion of mosquitoes and insects is a random motion.

(2) The motion of dust or smoke particles in the air is also random motion.

(3) The Brownian motion of a gas or liquid molecules along a zig-zag path is an example of random motion.



Brownian movement of particles in liquid.

(ii). Rotatory Motion:- "The spinning motion of a body about its axis is called its rotatory motion".

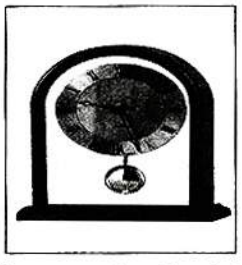
Examples

(1) Motion of wheel about its axis

(2) Motion of earth around its own axis

(3) Motion of steering wheel

(iii). Vibratory Motion:- "To and fro motion of a body about its mean position is known as vibratory motion".



Vibratory motion of pendulum

Examples:-

(1) Motion of pendulum

(2) Motion of see-saw

(3) A baby in cradle has to and fro motion about its axis. So its motion is called vibratory motion.

Q.4 Differentiate between Scalars and Vectors quantities.

Ans. Scalar Quantities:- "A physical quantity which can be completely described by its magnitude and unit is called a scalar quantity". The magnitude of a quantity means its numerical value with suitable unit.

Examples: mass, length, time, speed, volume, work and energy etc..

Vector quantities:- "A vector quantities can be described completely by magnitude and direction".

Examples: velocity, displacement, force, momentum, torque, etc.

Q.5 How is a vector represented?

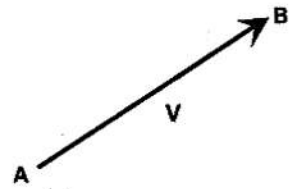
Ans. A vector is represented by two methods symbolically and graphically.

i. Symbolically

Symbolically we generally use bold letters to represent vector quantities, such as **F**, **a**, **d** or a bar or arrow over or below their symbols such as $\bar{F}$, $\bar{a}$, $\bar{d}$ or $\vec{F}$, $\vec{a}$ and $\vec{d}$ or $\underline{F}$, $\underline{a}$, $\underline{d}$, $\underline{F}$, $\underline{a}$, $\underline{d}$.

ii. Graphically

Graphically, a vector can be represented by a straight line with an arrow head at its one end. In figure, the line AB with arrow head of B represents a vector V. The length of the line AB gives the magnitude of the vector V on a selected scale. While the arrow head of the line from A to B gives the direction of the vector V.



Graphically representation of vector

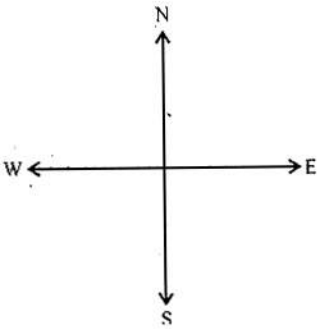
Example 2.1

Represent a force of 80N acting toward North or East.

Solution

Step 1

Draw the directions.

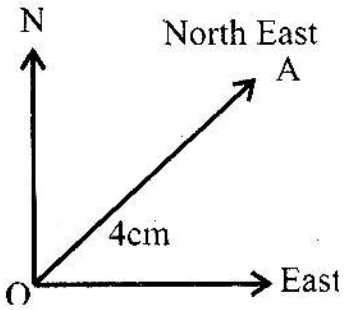


Step 2

Select a suitable scale to represent the given vector.

i, e 20 N = 1cm

80 N = 4cm



Step 3

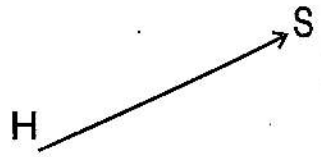
Draw a line according to the scale in the direction of the vector. In this case, draw a line OA of length 4cm along North-East.

Step 4

Put an arrow head at the end of the line. In this case arrow head is at point A. Thus, the line OA will represent a vector i.e., the force of 80N acting towards North-East.

Q.6 What do you know about position?

Ans. Position:- "The distance & direction of a body from fixed point shows the position of a body" . **OR**

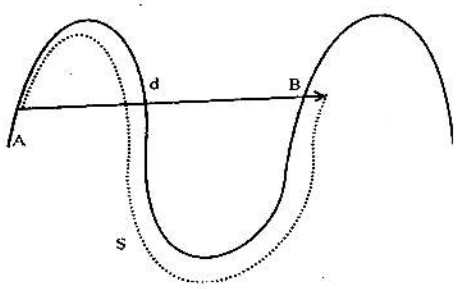


"The term position describes the location of a place or a point with respect to some reference point called origin."

Example: We want to describe the position of our school from our home. Let the school be represented by S and home by H. the position of your school from your home will be represented by a straight line HS in the direction from H to S as shown in figure.

Q.7 Differentiate between Distance and Displacement.

Ans. Distance: "Length of a path between two points is called the distance between those points".



Distance is scalar quantity and is represented by S

Displacement:- "Displacement is the shortest distance between two points which has magnitude and direction". It is a vector quantity and represented by **d.**

Q.8 Differentiate between Speed and Velocity

Ans. "The distance covered by a body in unit time is called its speed".

It is a scalar quantity.

Formula: If S is the distance covered by body in time 't', then.

$$\text{Speed} = \frac{\text{Distance covered}}{\text{time taken}}$$

$$\text{i.e } v = \frac{s}{t}$$

or Distance = Speed × Time

or $S = vt$ .....(2.1)

Here S is the distance covered by the body, v is its speed and t is the time taken by it.

Distance is a scalar; therefore, speed is also a scalar quantity. SI unit of speed is metre per second (ms^{-1}) or Kmh^{-1}.

Velocity:- "The rate of displacement of a body is called its velocity".

Formula: If "d" is the displacement covered by a body in time 't', then

$$\text{Velocity} = \frac{\text{displacement}}{\text{time}}$$

or $v = \frac{d}{t}$

$d = vt$ .....(2.2)

Here d is the displacement of the body moving with velocity **v** in time t. SI unit of velocity is the same as speed i.e., metre per second (ms^{-1}). Or Kmh^{-1} It is a vector quantity.

Note:

Speedometer of a car tells the speed only whereas ships & aeroplanes have meters which tell speed & direction so velocity is observed through meters of ships & aeroplanes.

Q.9 Define uniform Speed and uniform velocity.

Ans: A body has uniform speed if it covers equal distances in equal intervals of time however small the interval may be.

Uniform Velocity

A body has uniform velocity if it covers equal displacement in equal intervals of time however small the interval may be.

Example 2.2

A sprinter completes its 100 metre race in 12s. Find its average speed.

Solution

Total distance = s = 100 m

Total time taken = t = 12 s

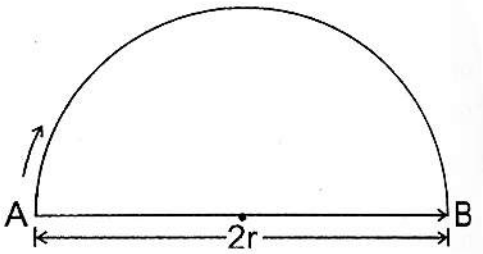
$$\text{Average Speed} = \frac{\text{Total distance}}{\text{Total time}}$$

$$\text{Average Speed} = \frac{100}{12} = 8.33 ms^{-1}$$

Thus the speed of the sprinter is $8.33 ms^{-1}$.

Example 2.3

A cyclist completes half round of a circular track of radius 318m in 1.5 minutes. Find its speed and velocity.



Solution

Radius = r = 318 m

Time taken = t = 1.5 minutes

= $1.5 \times 60 = 90$ sec

Distance covered = $\pi \times$ radius

Distance covered = $3.14 \times 318m = 999m$

Displacement = 2 r

Displacement = $2 \times 318m = 636$ m

$$\text{speed} = \frac{\text{dis tan ce}}{\text{time}}$$

$$v = \frac{s}{t}$$

$$\text{speed} = \frac{999}{90} = 11.1 ms^{-1}$$

$$\text{velocity} = \frac{\text{displacement}}{\text{time}}$$

$$v = \frac{d}{t}$$

$$\text{velocity} = \frac{636}{90} = 7.07 ms^{-1}$$

Thus speed of the cyclist is $11.1 ms^{-1}$ along the track and its velocity is about $7.1 ms^{-1}$ along the diameter AB of the track.

Q.10 Define Acceleration and write its formula.

Ans: Acceleration is defined as the rate of change of velocity of a body.

Formula: Suppose a body is moving with initial velocity 'v_i' after time '**t**' its velocity becomes v_f. then.

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

$$\text{Acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time}}$$

$$a = \frac{v_f - v_i}{t} \quad \ldots\ldots\ldots (2.3)$$

SI unit of acceleration is metre per second per second (ms^{-2}).

Q.11 Define Uniform Acceleration

Ans: A body has uniform acceleration if changes in velocity are equal in equal intervals of time, however small the interval may be.

Q.12 What is meant by positive and negative acceleration?

Ans: Positive acceleration: Acceleration of a body is positive if the velocity of body increases with time. The direction of this acceleration is the same in which the body is moving without change in its direction.

Negative acceleration: Acceleration of a body is negative if velocity of the body decreases with time. The direction of negative acceleration is opposite to the direction in which the body is moving. Negative acceleration is also called deceleration or retardation.

Example 2.4 A car starts from rest. Its velocity becomes $20ms^{-1}$ in 8s. Find its acceleration.

Solution

Initial velocity = $v_i = 0\ ms^{-1}$

Final velocity = $v_f = 20\ ms^{-1}$

Time taken = $t = 8\ s$

As $a = \frac{v_f - v_i}{t}$

Or $a = \frac{20 - 0}{8}$

$a = 2.5\ ms^{-2}$

Example 2.5

Find the retardation produced when a car moving at a velocity of $30ms^{-1}$ slows down uniformly to $15ms^{-1}$ in 5s.

Solution

Initial velocity = $v_i = 30ms^{-1}$

Final velocity = $v_f = 15ms^{-1}$

Change in velocity = $v_f - v_i$

$= 15 - 30$

$= -15\ ms^{-1}$

Time taken = $t = 5\ s$

$a = ?$

as $\text{Acceleration} = \dfrac{\text{change in velocity}}{\text{time interval}}$

or $a = \dfrac{-15}{5} = -3ms^{-2}$

So deceleration of the car is $3ms^{-2}$.

Q.13 What is meant by graph?

Ans. Graphical Analysis of Motion

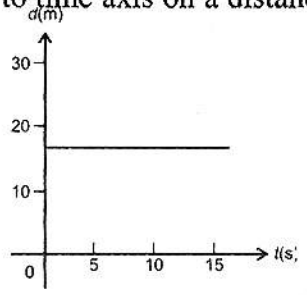
A graph is a relation between two physical quantities which may be straight line or curved line. The quantities between which a graph is plotted are called the variables. One of the quantities is called the independent quantity and the other quantity, is called dependent quantity. Graph is drawn between two mutually perpendicular lines called x–axis and y–axis. The point where these two lines meets is called origin. Independent quantities are taken on x–axis and dependent quantities are taken on y–axis.

Distance-Time Graph

It is useful to represent the motion of objects using graphs. In a distance-time graph, time is taken along horizontal axis while vertical axis shows the distance covered by the object.

Q.14 Explain graphically that object is at rest.

Ans. In the graph, the distance moved by the object with time is zero. That is, the object is at rest. Thus a horizontal line parallel to time axis on a distance-time graph shows that speed of the object is zero.

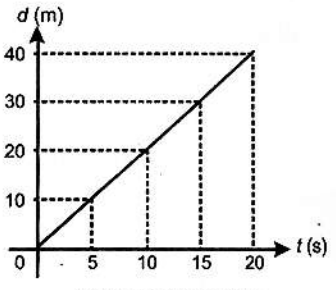


Distance-time graph when the object is at rest

Q.15 Sketch the distance time graph for a body starting from rest. How will you determine the speed of a body from this graph?

Ans: The speed of an object is said to be constant if it covers equal distances in equal intervals of time. The distance-time graph as shown in figure is a straight line. Its slope gives the speed of the object. Consider two points A and B on the graph.

Speed of the object = slope of line AB



Distance-time graph showing constant speed

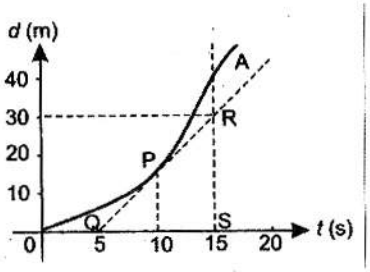
$$= \frac{\text{distance EF}}{\text{time CD}}$$

$$= \frac{20\text{m}}{10\text{s}} = 2\text{ms}^{-1}$$

The speed found from the graph is 2ms^{-1}.

Q.16 What would be the shape of a speed-time graph of a body moving with variable speed?

Ans: When an object does not cover equal distances in equal intervals of time then its speed is not constant. In this case the distance-time graph is not a straight line as shown. The slope of the curve at any point can be found from the slope of the tangent at that point. For example,



Distance-time graph showing variable speed

$$\text{Slope of the tangent at P} = \frac{\text{RS}}{\text{QS}}$$

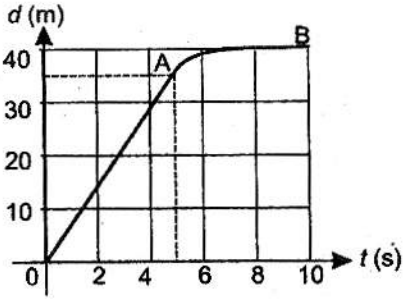
$$= \frac{30\text{m}}{10\text{s}} = 3\text{ms}^{-1}$$

Thus, speed of the object at P is 3ms^{-1}. The speed is higher at instants when slope is greater; speed is zero at instants when slope is horizontal.

Example 2.6

Figure shows the distance-time graph of a moving car. From the graph, find

(a) The distance car has travelled.
(b) The speed during the first five seconds.
(c) Average speed of the car.
(d) Speed during the last 5 seconds.



Distance-time graph of a car

Solution

a. Total distance travelled = 40 m

b. Distance travelled during first 5 s is 35 m

$$\therefore \quad \text{Speed} = \frac{35\text{m}}{5\text{s}}$$

$$= 7\text{ ms}^{-1}$$

c. $$\text{Average speed} = \frac{40\text{m}}{10\text{s}}$$

$$= 4\text{ ms}^{-1}$$

d. Distance moved during the last 5 s = 5 m

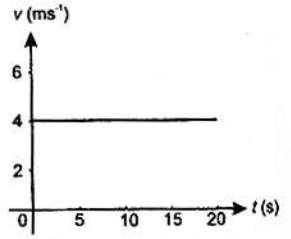
$$\therefore \quad \text{Speed} = \frac{5\,\text{m}}{5\,\text{s}} = 1\ \text{ms}^{-1}$$

Speed-time Graph

In a speed time graph, time is taken along x-axis and speed is taken along y-axis.

Q.17 Explain graphically object moving with constant speed.

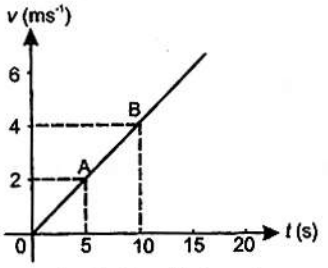
Ans. When the speed of an object is constant i.e (4 ms^{-1}) with time, then the speed time graph will be a horizontal line parallel to time axis along x-axis as shown in figure. In other words, a straight line parallel to time axis represents constant speed of the object.



Speed-time graph showing constant speed

Q.18 Explain graphically object moving with uniformly changing speed (uniform acceleration)

Ans. Let the speed of an object be changing uniformly. In such a case speed is changing at constant rate. Thus its speed time graph would be a straight line such as shown in figure. A straight line means that the object is moving with uniform acceleration. Slope of the line gives the magnitude of its acceleration.



Graph of an object moving with uniform acceleration

Example 2.7

Find the acceleration from speed-time graph shown in figure

Solution

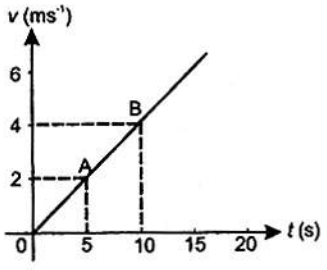
On the graph in figure, point A gives speed of the object as 2 ms^{-1} after 5 s and point B gives speed of the object as 4 ms^{-1} after 10 s.

As acceleration = slope of AB

$$\text{where} \quad \text{slope} = \frac{\text{Change in velocity}}{\text{Time interval}}$$

$$\therefore \text{ acceleration} = \frac{v_f - v_i}{t_f - t_i}$$

$$\therefore \text{ acceleration} = \frac{4-2}{10-5}$$



Graph of an object moving with uniform acceleration

$$= \frac{2}{5} = 0.4\,ms^{-2}$$

Speed-time graph in figure gives acceleration of the object as 0.4 ms^{-2}

Example 2.8

Find the acceleration from speed-time graph shown in figure

Solution

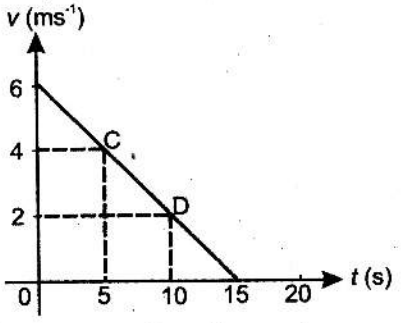
The graph in figure shows that the speed of the object is decreasing with time. The speed after 5 s is 4 ms^{-1} and it becomes 2 ms^{-1} after 10s.

As acceleration = slope of CD

$$\therefore \text{acceleration} = \frac{v_f - v_i}{t_f - t_i}$$

$$= \frac{2-4}{10-5}$$

$$= -\frac{2}{5} = -0.4ms^{-2}$$



Graph of an object moving with uniform deceleration

Speed time graph in figure gives negative slope. Thus, the object has deceleration of 0.4ms^{-2}

Q.19 Sketch a velocity time graph for the motion of the body. From the graph explaining each step calculate total distance covered by the object.

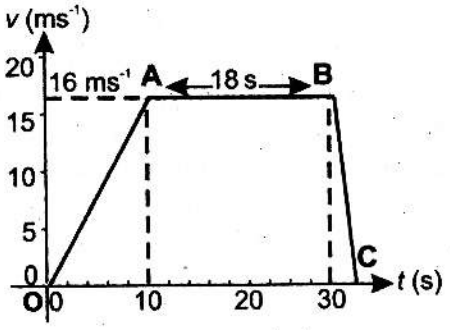
Ans. The area under a speed-time graph represents the distance travelled by the object. If the motion is uniform then the area can be calculated using appropriate formula for geometrical shapes represented by the graph.

Example 2.9

A car moves in a straight line. The speed-time graph of its motion is shown in figure.

From the graph, find

a. Its acceleration during the first 10 seconds.
b. Its deceleration during the last 2 seconds.
c. Total distance travelled.
d. Average speed of the car during its journey.



Speed-time graph of a car during 30 seconds

SOLUTION

a. Acceleration during the first 10 seconds

$$= \frac{\text{change in velocity}}{\text{time taken}}$$

$$= \frac{16-0}{10}$$

$$= 1.6\ ms^{-2}$$

b. Acceleration during the last 2 seconds

$$= \frac{0-16}{2}$$

$$= -8\ ms^{-2}$$

c. Total distance travelled

= area under the graph (trapezium OABC)

$$= \frac{1}{2}(\text{sum of parallel sides}) \times \text{Perpendicular distance between parallel sides}$$

$$= \frac{1}{2}(18+30)\times(16)$$

$$= \frac{1}{2}(48)\times(16)$$

$$= 384\ m$$

d. Average speed $= \dfrac{\text{Total distance covered}}{\text{Time taken}}$

$$= \frac{384}{30} = 12.8\ ms^{-1}$$

Q.20 What are the equations of motion?

Ans. There are three basic equations of motion of bodies moving with uniform acceleration. These equations relate initial velocity, v_i final velocity, v_f acceleration, **a** time and distance covered by a moving body. In these equations of motion we suppose the motion of a body is along a straight line. Hence, we consider only the magnitude of displacements, velocities, and acceleration along straight line.

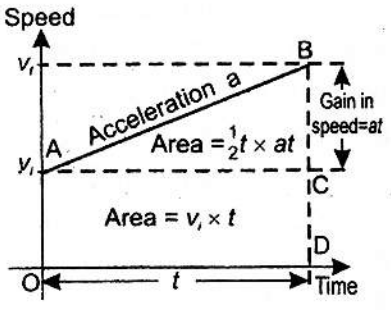
Q.21 Derive first equation of motion. $V_f = v_i + at$.

Ans. Consider a body is moving with initial velocity v_i in a straight line with uniform acceleration **a**. its velocity becomes v_f after time **t**. The motion of body is described by speed-time graph by line AB. The slope of line AB is acceleration "a".

$$\text{Slope of line AB} = a = \frac{BC}{AC} = \frac{BD-CD}{OD}$$

as $BD = v_f$ $CD = v_i$ and $OD = t$

Hence $a = \dfrac{v_f - v_i}{t}$



Speed-time graph. Area under the graph gives the distance covered by the body

or $v_f - v_i = at$

$\therefore v_f = v_i + at$

Q.22: Derive second equation of motion. $S = v_i t + \frac{1}{2} a t^2$

Ans. Consider a body is moving with initial velocity "v_i" in a straight line with uniform acceleration **a**. its velocity becomes "v_f" after time "**t**". The motion of body is described by speed-time graph by line AB. The slope of line AB is acceleration "**a**". the total distance covered by the body is shown by the shaded area under the line AB.

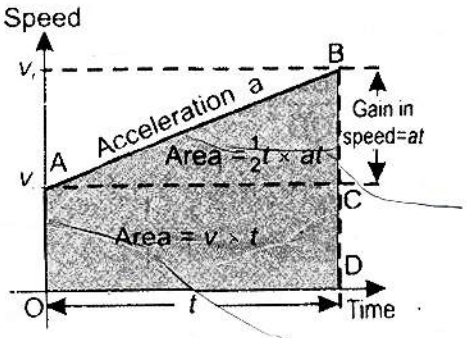
In speed-time graph shown in figure, the total distance S travelled by the body is equal to the total area OABD under the graph. That is Total distance S = area of (rectangle OACD + triangle ABC)

Area of Rectangle *OACD* $= OA \times OD$

$= v_i \times t$

Area of the Triangle ABC $= \frac{1}{2}(AC \times BC)$

$= \frac{1}{2} t \times at$



Speed-time graph. Area under the graph gives the distance covered by the body

Since Total area OABD = area of rectangle OACD + area of triangle ABC

Putting values in the above equation, we get

$$S = v_i t + \frac{1}{2} t \times at$$

$$S = v_i t + \frac{1}{2} at^2$$

Q.23: Derive third Equation of motion. $2as = V_f^2 - V_i^2$

Consider a body is moving with initial velocity "v_i" in a straight line with uniform acceleration **a**. its velocity becomes "v_f" after time "**t**". The motion of body is described by speed-time graph by line AB. The slope of line AB is acceleration "**a**". the total distance covered by the body is shown by the shaded area under the line AB. The total distance S travelled by the body is given by the total area OABD under the graph.

Total area of trapezium OABD = S =

$\frac{1}{2}$[Sum of parallel sides] x perpendicular distance between parallel sides

Total area OABD = $S = \frac{OA + BD}{2} \times OD$

Or $2S = (OA + BD) \times OD$

Multiplying both sides by $\frac{BC}{OD}$

$$2 \times \frac{BC}{OD} \times S = (OA + BD) \times OD + \frac{BC}{OD}$$

So $$2 \times \frac{BC}{OD} \times S = (OA + BD) \times BC$$

$$2 \times \frac{BC}{OD} \times S = (OA + BD) \times (BD - CD)$$

Since $\frac{BC}{OD} = a$

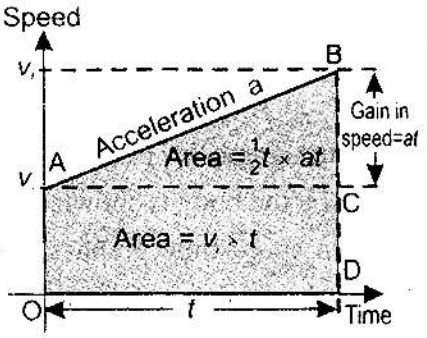
$$2as = (V_i + V_f)(V_f - V_i)$$

$$2as = V_f^2 - V_i^2$$

Putting the values in the above equation we get

$2S \times a = (v_i + v_f) \times (v_f - v_i)$

$\boxed{2as = v^2_f - v^2_i}$



Speed-time graph. Area under the graph gives the distance covered by the body

Example 2.10

A car travelling at 10 ms^{-1} accelerates uniformly at 2 ms^{-2}. Calculate its velocity after 5 s.

Solution

$v_i = 10\ ms^{-1}$

$a = 2\ ms^{-2}$

$t = 5s$

$v_f = ?$

Using the first equation

$v_f = vi + at$

$v_f = 10 + 2 \times 5$

or $v_f = 20\ ms^{-1}$

The velocity of the car after 5 s is 20 ms^{-1}

Examples 2.11

A train slows down from 80 kmh^{-1} with a uniform retardation of 2 ms^{-2}. How long will it take to attain a speed of 20kmh^{-1}?

Solution

$v_i = 80\ kmh^{-1}$

$= \frac{80 \times 1000}{60 \times 60}$

$= 22.2\ ms^{-1}$

$v_f = \frac{20 \times 1000}{60 \times 60}$

$= 5.6\ ms^{-1}$

$a = -2\ ms^{-2}$

$t = ?$

Using first equation

$v_f = v_i + at$

$t = \frac{v_f - v_i}{a}$

$\frac{5.6 - 22.2}{-2}$

$t = 8.3\ s$

Thus the train will take 8.3 s to attain the required speed.

Example 2.12

A bicycle accelerates at 1 ms^{-2} from an initial velocity of 4 ms^{-1} for 10 s. find the distance moved by it during this interval of time.

Solution

$v_i = 4ms^{-1}$

$a = 1ms^{-2}$

$t = 10s$

$s = ?$

Using the second equation

$S = v_i t + \frac{1}{2} at^2$

$S = 4 \times 10 + \frac{1}{2} \times 1 \times (10)^2$

$= 40 + \frac{1}{2} \times 100$

$= 40 + 50$

$= 40 + 50 = 90\ m$

Thus, the bicycle will move 90 metres in 10 seconds.

Example 2.13

A car travels with a velocity of 5 ms^{-1}. It then accelerates uniformly and travels a distance of 50 m. If the velocity reached is 15ms^{-1}. Find the acceleration and the time to travel this distance.

Solution

$v_i = 5\ ms^{-1}$

$s = 50\ m$

$v_f = 15\ ms^{-1}$

$a = ?$

$t = ?$

Putting values in the third equation of motion, we get

$2aS = v_f^2 - v_i^2$

$\therefore\ 2a \times 50 = (15)^2 - (5)^2$

$(100)\,a = (225 - 25)$

$100a = 200$

$a = \frac{200}{100}$

or $a = 2ms^{-2}$

Using first equation of motion to find t, we get

$v_f = v_i + at$

$\therefore\ 15 = 5 + 2 \times t$

$15 - 5 = 2 \times t$

or $2 \times t = 10$

or $t = \frac{10}{2}$

$= 5\ s$

Thus, the acceleration of the car is 2 ms^{-2} and it takes 5 seconds to travel 50m distance.

Q.23 Explain motion of freely falling bodies and write equations of motion for freely falling bodies.

Ans: Galileo was the first scientist to notice that all the freely falling bodies have the same acceleration bodies of different masses from the leaning tower of Pisa. He found that all of them reach the ground at the same time. **The acceleration of freely falling bodies is called gravitational acceleration. It is denoted by '*g*'. On the surface of the Earth, its value is approximately 10 ms^{-2}.**

For bodies falling down freely '*g*' is positive and is negative for bodies moving up.

Equations of motion are in this case

$V_f = v_i + gt$

$S = v_i t + \frac{1}{2} gt^2$

$2gs = v_f^2 - v_i^2$

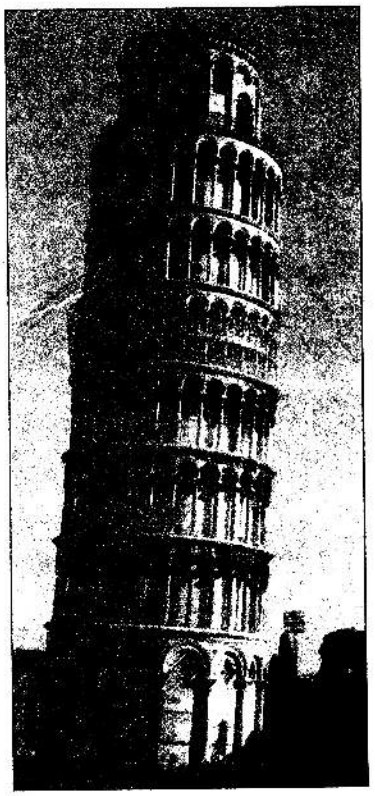
Example 2.14

A stone is dropped from the top of a tower. The stone hits the ground after 5 seconds.

Find

a) The height of the tower.

b) The velocity with which the stone hits the ground.



Leaning Tower of Pisa

Solution

Initial velocity = $v_i = 0$

Gravitational acceleration = $g = 10\ ms^{-2}$

$t = 5s$

$s = h = ?$

$v_f = ?$

a) Applying the equation

$h = vit + \frac{1}{2} g t^2,$

$h = 0 \times 5 + \frac{1}{2} \times 10 \times (5)^2$

or $h = 0 + 125$

$h = 125m$

b) Applying the equation

$v^2_f - v^2_i = 2gh$

$v^2_f - (0)^2 = 2 \times 10 \times 125$

$v^2_f = 2500$

$\sqrt{v_f^2} = \sqrt{2500}$

$v_f = 50ms^{-1}$

Thus the height of the tower is 125 metres and it will hit the ground with a velocity of $50\,ms^{-1}$.

Example 2.15

A boy throws a ball vertically up. It returns to the ground after 5 seconds. Find

a. The maximum height reached by the ball.

b. The velocity with which the ball is thrown up.

Solution

Initial velocity (upward) = $v_i = ?$

Gravitational acceleration = $g = -10\ ms^{-2}$
Time for up and down motion $t_o = 5\ s$
Velocity at maximum height $v_f = 0$
$S = h = ?$

As the acceleration due to gravity is uniform, hence the time t taken by the ball to go up will be equal to the time taken to come down = $\frac{1}{2} t_o$

or $t = 1/2 \times 5 = 2.5\ s$
$v_f = v_i + gt$
$0 = v_i - 10 \times 2.5$
$= v_i - 25$
$\Rightarrow v_i = 25\ ms^{-1}$

a) Applying the equation
$h = v_i t + \frac{1}{2} gt^2$
$h = 25 \times 2.5 - \frac{1}{2} \times 10 \times (2.5)^2$
or $h = 62.5 - 31.25 = 31.25m$

Thus, the ball was thrown up with a speed of 25 ms^{-1} and the maximum height to which the ball rises is 31.25 m.

MULTIPLE CHOICE

2.1 Encircle the correct answer from the given choices:

1. A body has translatory motion if it moves along a
(a) Straight line (b) circle
(c) line without rotation (d) curved path

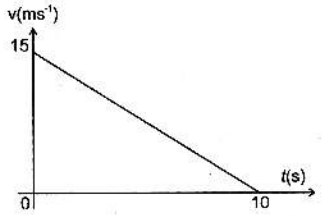
2. The motion of a body about an axis is called
(a) Circular motion (b) rotatory motion
(c) vibratory motion (d) random motion

3. Which of the following is a vector quantity?
(a) speed (b) distance
(c) displacement (d) power

4. If an object is moving with constant speed then its distance time graph will be a straight line.
(a) along time-axis
(b) along distance –axis
(c) parallel to time -axis
(d) inclined to time- axis

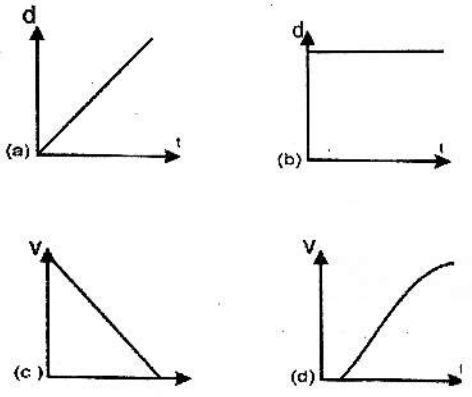
5. A straight line parallel to time-axis on a distance-time graph tells that the object is
(a) moving with constant speed
(b) at rest
(c) moving with variable speed
(d) in motion

6. The speed–time graph of a car is shown in the figure, which of the following statement is true?



(a) car has an acceleration of $1.5ms^{-2}$
(b) car has constant speed of $7.5\ ms^{-1}$
(c) distance travelled by the car is 75m
(d) average speed of the car is $15\ ms^{-1}$

7. Which one of the following graphs is representing uniform acceleration?



8. By dividing displacement of a moving body with time, we obtain

(a) speed (b) acceleration
(c) velocity (d) deceleration

9. A ball is thrown vertically upward. Its velocity at the highest point is

(a) $-10\ ms^{-1}$ (b) zero
(c) $10\ ms^{-2}$ (d) none of them

10. A train is moving at a speed 36 kmh^{-1} .Its speed expressed in ms^{-1}

(a) $10\ ms^{-1}$ (b) $20\ ms^{-1}$
(c) $25\ ms^{-1}$ (d) $30\ ms^{-1}$

11. A change in position is called

(a) speed (b) velocity
(c) displacement (d) distance

12.A car starts from rest. It acquires a speed of 25 ms^{-1} after 20 s. The distance moved by the car during this time is

(a) 31.25 m (b) 250 m
(c) 500 m (d) 5000 m

13.The fastest bird falcon has speed kmh^{-1}.

(a) 100 (b) 200
(c) 300 (d) 400

14.The average speed of cheetah run at the speed.

(a) $60kmh^{-1}$ (b) $75kmh^{-1}$
(c) $70kmh^{-1}$ (d) $80kmh^{-1}$

15.The unit of acceleration is :

(a) ms^{-1} (b) ms
(c) ms^{-2} (d) ms^{2}

16. Displacement is a quantity.

(a) Scalar (b) Vector
(c) Both a & b (d) None of these

17. The slope of speed time graph is called

(a) Distance (b) displacement
(c) Velocity (d) Acceleration

18. The value of gravitational acceleration when a body is moving in downward direction is

(a).$10ms^{-1}$ (b) $10ms^{-2}$
(c).10m (d) -10ms

19.The slope of distance time graph shows

(a) speed (b) Velocity
(c).acceleration (d) Distance

20.The motion of Ferris wheel is

(a) Translatory (b) Vibratory

(c). Rotatory (d). Circular

21. First equation of motion is

(a) $V_f = vi + at$

(b) $S=vit+\frac{1}{1}At^2$

(c) $2as_= v_f^2 + vi^2$

(d) All of these

22. If an object is moving with a uniform changing speed then speed time graph is

(a) straight (b) variable

(c) parallel to time axis (d) All of these

23. The unit of velocity and speed is

(a) ms (b) ms^{-2}

(c) ms^{-3} (d)ms^{-1}

ANSWERS

1.	c	**2.**	b	**3.**	c	**4.**	d	**5.**	b
6.	c	**7.**	c	**8.**	c	**9.**	b	**10.**	a
11.	d	**12.**	b	**13.**	b	**14.**	c	**15.**	c
16.	b	**17.**	d	**18.**	b	**19.**	a	**20.**	a
21.	a	**22.**	a	**23.**	d				

SHORT QUESTIONS

Q.1 Can a body moving at a constant speed have acceleration?

Ans. Yes!a body moving with constant speed have acceleration if the direction of moving body changes, which produce acceleration ɘ ƍ dɐɹɹɐp pɯ oʌ ɹƍ ɹ ɐ ɔɹɔ pʍ ɪɪɟ nu ƃoɯ sdəəp ·

Q.2 How do riders in a Ferris wheel possess translatory motion but not circular motion?

Ans. Since the Ferris wheel is moving without rotation on circular path so the rider in Ferris wheel possesses translatory motion.

Q. 3 Why cannot vector quantities be added and subtracted like scalar quantities?

Ans. Vector and scalar quantities cannot be added and subtracted by same method because vector quantities are added by **head to tail rule** while scalars are added by **algebraic method**.

Q.4 How are vector quantities important to us in our daily life?

Ans. With the help of vector quantities we can explain the position of object with distance and direction.

NUMERICAL PROBLEMS

Q. 2.1 A train moves with a uniform velocity of 36 kmh^{-1} for 10s. Find the distance travelled by it.

Given data

$v = 36\ km/h$

$= \frac{36 \times 1000}{3600} = 10\ ms^{-1}$

$t = 10\ see$

$S = ?$

Solution

We Know

$S = v \times t$

$S = 10 \times 10 = 100\ m$

Q. 2.2 A train starts from rest. It moves through 1 km in 100 s with uniform acceleration. What will be its speed at the end of 100 s.

Given data

$V_i = 0$

$t = 100\ sec$

$S = 1\ km = 1000\ m$

$V_f = ?$

Solution

We know

$S = v_{av} \times t$

$S = \left(\frac{v_f + v_i}{2}\right) t$

$1000 = \left(\frac{v_f + 0}{2}\right) 100$

$1000 \times 2 = (v_f)\ (100)$

$\frac{2000}{100} = v_f$

$\boxed{V_f = 20\ ms^{-1}}$

Q.2.3 A car has a velocity of 10 ms^{-1}. It accelerates at 0.2 ms^{-2} for half minute. Find the distance travelled during this time and the final velocity of the car.

Given data

$a = 0.2\ m/s^2$

$V_i = 10\ m/s$

$t = 0.5\ min$

$= 0.5 \times 60\ sec$

$t = 30\ sec$

$S = ?$

$V_f = ?$

Solution: We know

$V_f = vi + at$

$V_f = 10 + (0.2)\ (30)$

$= 10 + 6$

$V_f = 16 m/s$

$S = v_{av} \times t$

$S = \frac{v_f + v_i}{2} t$

$S = \left(\frac{16 + 10}{2}\right) 30$

$S = \left(\frac{\cancel{26}^{13}}{\cancel{2}}\right) 30$

$\boxed{S = 390\ m}$

Q. 2.4 A tennis ball is hit vertically upward with a velocity of 30ms^{-1}. It takes 3 s to reach the highest point. Calculate the maximum height reached by the ball. How long it will take to return to ground?

Given data

$V_i = 30\ ms^{-1}$

$t = 3\ sec$

Total time = ?

$S = ?$
$V_f = 0$
$g = -10 m/s^2$
Solution: We know
$2gs = v_f^2 - v_i^2$
$2(-10)(S) = (0)^2 - (30)^2$
$-20S = -900$
$S = \frac{-900}{-20}$

$\boxed{S = 45 \text{ m}}$

$$\text{Total time} = \begin{pmatrix}\text{Time to}\\ \text{reach}\\ \text{at Max}\\ \text{height}\end{pmatrix} + \begin{pmatrix}\text{Time to}\\ \text{reach}\\ \text{ground form}\\ \text{height}\end{pmatrix}$$

$= 3 + 3$

$\boxed{\text{Total time} = 6 \text{ sec}}$

Q. 2.5 A car moves with uniform velocity of 40 ms^{-1} for 5 s. It comes to rest in the next 10 s with uniform deceleration. Find (i) deceleration (ii) Total distance travelled by the car.

Given data
$v_i = 40$ m/s
$v_f = 0$
$a = ?$
$s = ?$
$t = 10$ sec
Solution: We know
$v_f = v_i + at$
$0 = 40 + a(10)$
$-40 = 10(a)$
$\frac{-40}{10} = a$

$\boxed{a = -4 ms^{-2}}$

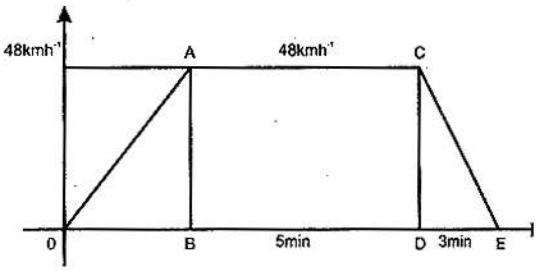
$s = vt$
$s = 40 \times 10 = 400$ m

Q 2.6 A train starts from rest with an acceleration of 0.5 ms^{-2}. Find its speed in kmh^{-1}, when it has moved through 100 m.

Given data
$V_i = 0$
$a = 0.5 m/s^2$
$s = 100$ m
$V_f = ?$
Solution: We know
$2aS = v_f^2 - v_i^2$
$2(0.5)(100) = (v_f)^2 - (0)^2$
$100 = v_f^2 - o$
$\sqrt{100} = \sqrt{vf^2}$
$v_f = 10 ms^{-1}$
to convert in km / h
$v_f = \frac{10 \times 3600}{1000}$

$\boxed{V_f = 36 \text{ km } h^{-1}}$

Q. 2.7 A train staring from rest, accelerates uniformly and attains a velocity 48 kmh^{-1} in 2 minutes. It travels at this speed for 5 minutes. Finally, it moves with uniform retardation and is stopped after 3 minutes. Find the tota distance travelled by the train.



Given
$V_i = 0$
$t = 2 \text{ min} = 2 \times 60 = 120$ sec
$V_f = 48 \text{ kmh}^{-1} = \frac{48 \times 1000}{3600} = 13.33 ms^{-1}$
$S_1 = ?$

Solution: During first path

$S = V_{av} \times t$

$S_1 = \left(\frac{vf + vi}{2}\right) t$

$= \left(\frac{13.33 + 0}{2}\right)(120)$

$S_1 = 799.8\ ms^{-1}$

During second path

$t = 5\ min = 5 \times 60 = 300\ sec$

$v = 13.33\ ms^{-1}$

$S_2 = ?$

$S_2 = vt$

$= 13.33 \times 300$

$S_2 = 3999m$

During second path

$t = 3\ min = 3 \times 60 = 180\ sec$

$v_f = 0$

$v_i = 13.33\ ms^{-1}$

$s_3 = ?$

$S_3 = \left(\frac{v_f + v_i}{2}\right) t$

$= \left(\frac{0 + 13.33}{\cancel{2}}\right)\left(\frac{60}{\cancel{180}}\right)$

$= 13.33\ (60)$

$= 799.8m$

Total distance $= S_1 + S_2 + S_3$

$= 799.8 + 3999 + 799.8$

$S_T = 6000m$

Q 2.8 A cricket ball is hit vertically upwards and returns to ground 6 s later. Calculate (i) maximum height reached by the ball. (ii) Initial velocity of the ball.

Given data

$V_f = 0$

$S = ?$

$V_i = ?$

$g = -10m/s^2$

Total time = 6 sec $\Rightarrow$ Total time = [time to rearch at Max height] + [Time to reach ground]

$= 3 + 3\ s$

$= 6\ sec$

$t = 3sec$

Solution: We know

$V_f = v_i + gt$

$0 = v_i + (-10)(3)$

$-V_i = -30$

$v_i = 30ms^{-1}$

$2gs = v_f^2 - v_i^2$

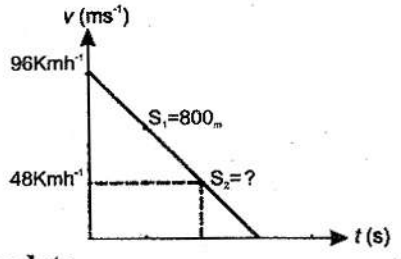
$-2 \times 10 \times S = (0)^2 - (30)^2$

$-20S = 0 - 900$

$S = \frac{-900}{-20}$

$S = 45\ m$

Q 2.9 When brakes are applied, the speed of a train decreases from 96 kmh^{-1} to 48 kmh^{-1} in 800 m. How much further will the train move before coming to rest? (Assuming the retardation to be constant).



Given data

$S_1 = 800m$

$V_i = 96\ kmh^{-1} = \frac{96 \times 1000}{3600} = 26.67 ms^{-1}$

$V_f = 48\ kmh^{-1} = \frac{48\times100}{3600} = 13.33 ms^{-1}$

S_2 = ? (Before stop the train)

Solution: We know

$2a\ S_1 = v_f^2 - V_i^2$

$2\ (a)\ (800) = (13.33)^2 - (26.67)^2$

$= 177.69 - 711.289$

$1600\ (a) = -533.5989$

$a = \frac{-533.5989}{1600}$

$a = 0.3335\ ms^{-2}$

To Find 's'

$2as_2 = v_f^2 - v_i^2$

$2\ (0.3335)\ (S_2) = (13.33)^2 - (0)^2$

$(0.667)\ S_2 = 177.6889$

$S_2 = \frac{177.6889}{0.667} = 266.62m$

Q. 2.10 In the above problem, find the time taken by the train to stop after the application of brakes.

Given data

$v_f = 0 ms^{-1}$

$v_i = 366.67\ ms^{-1}$

$a = 0.3335$ sec

t = ?

Solution: We know

$v_f = v_i + at$

$0 = 26.67 + (-0.3335)\ t$

$0 = 26.67 - (0.3335)\ (t)$

$26.67 = 0.3335\ t$

$\frac{26.67}{0.3333} = t \Rightarrow \boxed{t = 80\ s}$